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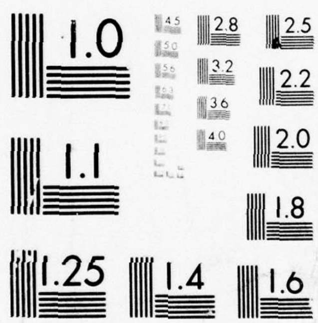

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OCEANIC FRONTAL ANALYSIS.

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ABSTRACT

A method is given for the analysis of thermal structure based on identification of water masses and localization of oceanic fronts. The resulting oceanic frontal analysis appears to offer a significant improvement over isotherm analysis, both with respect to objectivity of analysis method and information displayed.

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OCEANIC FRONTAL ANALYSIS

INTRODUCTION

Major water masses of the world ocean may be identified by their unique thermohaline relationship. In many oceanic areas water mass recognition may be made in the near surface layer on the basis of temperature characteristics alone. This is particularly true where water mass boundaries (oceanic fronts), such as the northern edge of the Gulf Stream, are readily apparent. Thus available, low cost instrumentation such as the expendable bathythermograph, can be used to differentiate between water masses, to locate their common boundary, and to determine thermal structure characteristics within each water mass. This report describes a method of preparing a thermal structure analysis based on water mass identification from bathythermograms, with particular emphasis on oceanic frontal analysis in the area between Cape Sable, Nova Scotia, and Cape Hatteras, North Carolina (Figure 1).

Oceanic frontal analysis assumes that (1) thermal structure (sea surface temperature, sonic layer depth) within a given water mass is relatively persistent over periods of several days, (2) fronts are indicated by strong horizontal temperature gradients, and (3) interaction between water masses follows characteristic and predictable patterns.

OCEANOGRAPHIC BACKGROUND

Prior to attempting oceanic frontal analysis, the analyst must determine the typical distribution and variation of oceanographic

parameters within the area. A review of oceanic literature may provide considerable information about water mass and frontal characteristics. For example, suppose the analyst wished to separate Gulf Stream observations from Slope Water observations to the north. Hansen (1970) determined that the center of the strongest temperature gradient marking the northern edge of the Gulf Stream had a mean temperature of 14.7°C at a depth of 200m. Thus the analyst would classify BT observations having a temperature equal to or greater than 14.7°C at 200m as Gulf Stream Water and those having a temperature less than 14.7°C at this depth as Slope Water. Additional information may be gained from careful examination of all available bathythermograms taken within each water mass. Bathymetry may also be of considerable help when defining water mass limits. For instance, coastal water overlying the continental shelf often has different temperature and salinity characteristics than oceanic water offshore. The 200m isobath was found to be a both realistic and convenient boundary between coastal (Shelf Water) and oceanic (Slope Water) off the northeastern United States.

Table 1 gives temperature ranges at specified depths for five water masses found in the area covered by Figure 1. Depths used are sufficiently deep so that the effect of temporal (diurnal, seasonal, annual) and spatial (latitudinal, longitudinal) temperature change is insignificant compared to temperature differences between water masses.

The criteria given were obtained from careful examination of more than 3,000 expendable BT observations taken in the study region and the National Oceanographic Data Center station data files.

Once water mass limits have been established it is desirable to determine the vertical thermal structure characteristics within each water mass. Mean monthly SST and SLD values should be known and if sound channels occur their temporal and spatial variation should be determined. Thermohaline characteristics can be determined from examination of oceanographic station data, thus providing a method for estimating salinity as a function of temperature and water mass. BT traces typical of each water mass and corresponding frontal zones provide visual means of water mass recognition. Figure 2 shows seasonal BT traces for the western North Atlantic Ocean.

Frontal zones must be located and their characteristics ascertained. Mixing across a front may occur as either overrunning at the surface or temperature inversions at depth. Overrunning may occur when warm water overrides cooler water (Gulf Stream Water over Slope Water) or when cooler, less saline (and thus less dense) water overrides warmer water (Shelf Water over Slope Water). Inversions occur most frequently in and adjacent to frontal zones, and are often an indicator that a front is nearby. Considerable seasonal variation in frontal strength may occur. For example, a front extends southeastward from Cape Cod into deep water during all seasons except winter. In summer the horizontal temperature gradient across this front may exceed the strength

Table 1

Water Mass Characteristics

Water Mass	Abbreviation	Temperature Characteristics
Sargasso	SA	$T200 \geq 17.0^{\circ}$ and $T400 \geq 16.5^{\circ}C$
Stream	ST	$15.0^{\circ} \leq T200 < 17.0^{\circ}C$ & $T400 < 16.5^{\circ}C$
Slope	SL	$9^{\circ} \leq T200 < 15.0^{\circ}C$
Scotian	SC	$T200 < 9^{\circ}C$
Shelf	SH	Bottom depth less than 200m.

T200: temperature at 200m

T400: temperature at 400m

of the gradient across the northern edge of the Gulf Stream. During winter, when cold air and increased winds cause mixing to the Shelf bottom, the Cape Cod front may be destroyed. Surface heating during summer causes the front between coastal water and oceanic water (slope front) to be obscured at the surface, although salinity observations and temperature inversions continue to indicate the presence of this front in the subsurface layer. Examples of BT traces representative of overrunning and inversions within frontal zones are also shown in Figure 2.

Considerable variation in frontal location may be observed over a period of several days. Wave-like meanders of major ocean currents occur at random intervals for reasons not fully understood. Gulf

Stream meanders greater than 100 km in length and 50 km in amplitude have been tracked downstream at speeds of about 8 km/day. Coastal water has been observed overlying oceanic water to depths exceeding 50m as much as 100 km offshore of the 200m isobath, probably as a result of wind-driven advection. Overrunning, inversions, and change of SST and SLD should be expected whenever frontal displacement occurs. Unfortunately, little can be learned from examination of historical data because of smoothing which occurs during the averaging process. Therefore, the analyst must examine either individual survey reports or compendiums of oceanic variability within a given area.

The rapid increase in number and accuracy of oceanographic observations which has occurred during the last decade has resulted in the observation of features which were previously little known. Warm eddies of Gulf Stream origin are an example of anomalous features in Slope Water that have been described in recent literature (Saunders, 1971). Once again it is necessary to examine original data or descriptive reports to determine frequency, speed of propagation, thermal characteristics, and cause.

ANALYSIS GUIDELINES

Information available to the analyst includes (1) periodic SST and BT reports, (2) occasional infrared (IR) data collected by airborne radiation thermometer (ART) observations from aircraft and high resolution infrared radiometer (HRIR) observations from satellites, (3) previous oceanic frontal analyses, and (4) background material

as derived in the previous section. The recommended procedure for preparing a 4-day composite analysis for the North Atlantic area defined in Figure 1 is given in steps 1 through 7 below. An oceanographic synopsis of much of the area can be found in Fisher (1972).

1. Scan the available BT's taken west of 60°W between 34° and 42°N during the 4-day reporting period. Observations falling within these limits should be initially checked for obvious errors and then identified by date (A through D, with A being the most recent date), SST (whole degrees, Celsius), and water mass (SA,ST,SL,SC,SH) using the criteria given in table 1. The water mass classifications may be expanded to include:

   a. Northern Edge (NE): SST equivalent to Gulf Stream values, temperature at 200m within Slope Water limits, presence of sound channel likely.

   b. Southern Edge (SE): SST equivalent to Gulf Stream values, temperature at 200m within Sargasso Water limits, depressed sound channel (warm water over isothermal layer) likely.

   c. Warm Eddy (WE): Taken in Slope Water with temperature at 200m equivalent to Gulf Stream values. SST may correspond to either Gulf Stream Water or Slope Water. In latter case a subsurface eddy exists and a strong positive thermocline will be found in the surface layer.

   d. Cold Eddy (CE): An eddy of water of Slope Water origin (temperature at 200m less than 15°C) surrounded by Sargasso Water.

For example, consider a BT report made on the next to last day of the reporting period and having an SST of 18.4°C, a temperature of 13.9° at 180m and a temperature of 5.0° at 400m. The value of 180m is below the upper limit of Slope Water (15°) at 200m and above the upper limit of Scotian Water (9°). Linear interpretation between the observed values at depth indicates a temperature of 13.0° at 200m, thus confirming that the observation was made in Slope Water. The report would thus be coded "B18SL".

2. Both ART and HRIR data are greatly influenced by the atmosphere and thus may be in error by several degrees Celsius. Although procedures for data correction are rapidly improving, the analyst frequently cannot be sure if corrections have been applied. Therefore, he should use these data to indicate presence or absence of gradients and, if present, the approximate temperature change across the gradient only. When satellite data are used, cloud contamination may obscure the surface thus requiring construction of a composite gradient from several days' data.

3. Once the data have been examined, coded, and plotted on a suitable base chart, fronts and eddies should be sketched in. After comparison with previous analyses, the corrected features should be drawn with a felt-tipped pen. Where no observations are present, but a feature is known to exist from previous reports, the feature should be drawn with a dashed line after adjustment for movement. A dashed line should also be used when the exact position of a feature

cannot be deduced from available data. When the presence of a transient feature, such as an eddy, has not been confirmed for at least two weeks, it should be removed from the analysis.

4. Surface temperature ranges across fronts and within water masses should be determined from SST observations and indicated on the analyses at appropriate intervals. In the present example, temperature ranges were omitted across the southern edge owing to a combination of sparse data and weak gradient. With the exception of Shelf Water, where southern and northern temperature regimes exist on either side of the Cape Cod front, a single SST range was given for each water mass. If a wide temperature range exists within a water mass, with minimum and maximum values widely separated from the majority of the observations, the range indicated on the analysis should be modified to reflect the majority of SST values. This is justified by frequent errors found in SST reports.

5. Surface current direction is indicated by arrow based primarily on frontal orientation. The right hand rule may be helpful in deep water in the northern hemisphere; with the palm of the hand on cold water and the fingers on warm water, the current will be in the direction of the extended thumb. Arrow size should be larger where strong currents are known to exist such as in the Gulf Stream. Oceanographic literature may provide specific examples helpful to the analyst. For example, maximum current speed is normally observed on the inshore side of the Gulf Stream (Stommel, 1966). Another paper (Bumpus, 1969)

indicates that current reversals may occur in Shelf Water subsequent to periods of low rainfall in summer.

6. Additional information of specific interest to particular users may be inferred in the absence of data. For example, a well-defined temperature inversion is known to exist along the edge of the Continental Shelf from Cape Hatteras to Cape Cod during all seasons except winter. A sound channel formed by the inversion could be of considerable aid to ASW units operating in that area. Although no recent BT observations may be available to show the inversion, the fact that it is a recurring feature is sufficient to predict it. Similarly, increased ambient noise should be expected from biological sources near frontal zones owing to increased marine life which occur there. Thus, this phenomenon can be predicted despite the fact that no recent bioacoustic data are available.

7. Comments pertinent to the analysis (drift rate of a subsurface warm eddy of Gulf Stream origin) or the user (strong surface ducting above the forementioned eddy) should be printed in the lower right hand corner of the analysis.

DISCUSSION AND CONCLUSION

An oceanic frontal analysis drawn in accordance with the above procedure is shown as Figure 3. Location of four oceanic fronts (northern and southern edges of the Gulf Stream, slope front, and Cape Cod front) and an equal number of water masses (Shelf, Slope, Gulf Stream, and Sargasso) are shown. Associated SST ranges and inferred

circulation are given. An anomalous feature in the form of a warm eddy is shown and amplifying information (expected eddy drift) given in the remarks section. Had the analysis been ASW oriented, amplifying information would have (1) defined areas of overrunning and temperature inversions and (2) briefly described their effect on sound propagation (surface ducting, sound channel, etc.).

Oceanic frontal analysis appears to offer a significant improvement over isotherm analyses, both with respect to objectivity of analysis method and amount and quality of information displayed. Annotated remarks provide particular information relative to the user's needs. When used in conjunction with the analyst's experience and predetermined water mass statistics additional thermal structure and sonic properties can be inferred.

REFERENCES

Bumpus, D. F. (1969). "Reversals in the surface drift in the Middle Atlantic Bight Area", Deep-Sea Research, Suppl. to Vol. 16, 17-23.

Fisher, A., Jr. (1972). "Environmental guide to the Virginia Capes Operating Area", Special Publication, Naval Oceanographic Office, 58p, (in preparation).

Hansen, D. V. (1970). "Gulf Stream Meanders between Cape Hatteras and the Grand Banks", Deep-Sea Research, 17(3), 495-511.

Saunders, P.M. (1971). "Anticyclonic eddies formed from shoreward meanders of the Gulf Stream", Deep-Sea Research, 18(12), 1207-1219.

Stommel, H. (1966). "The Gulf Stream", 2nd Edition, Univ. of Calif. Press and Cambridge University Press. 248p.

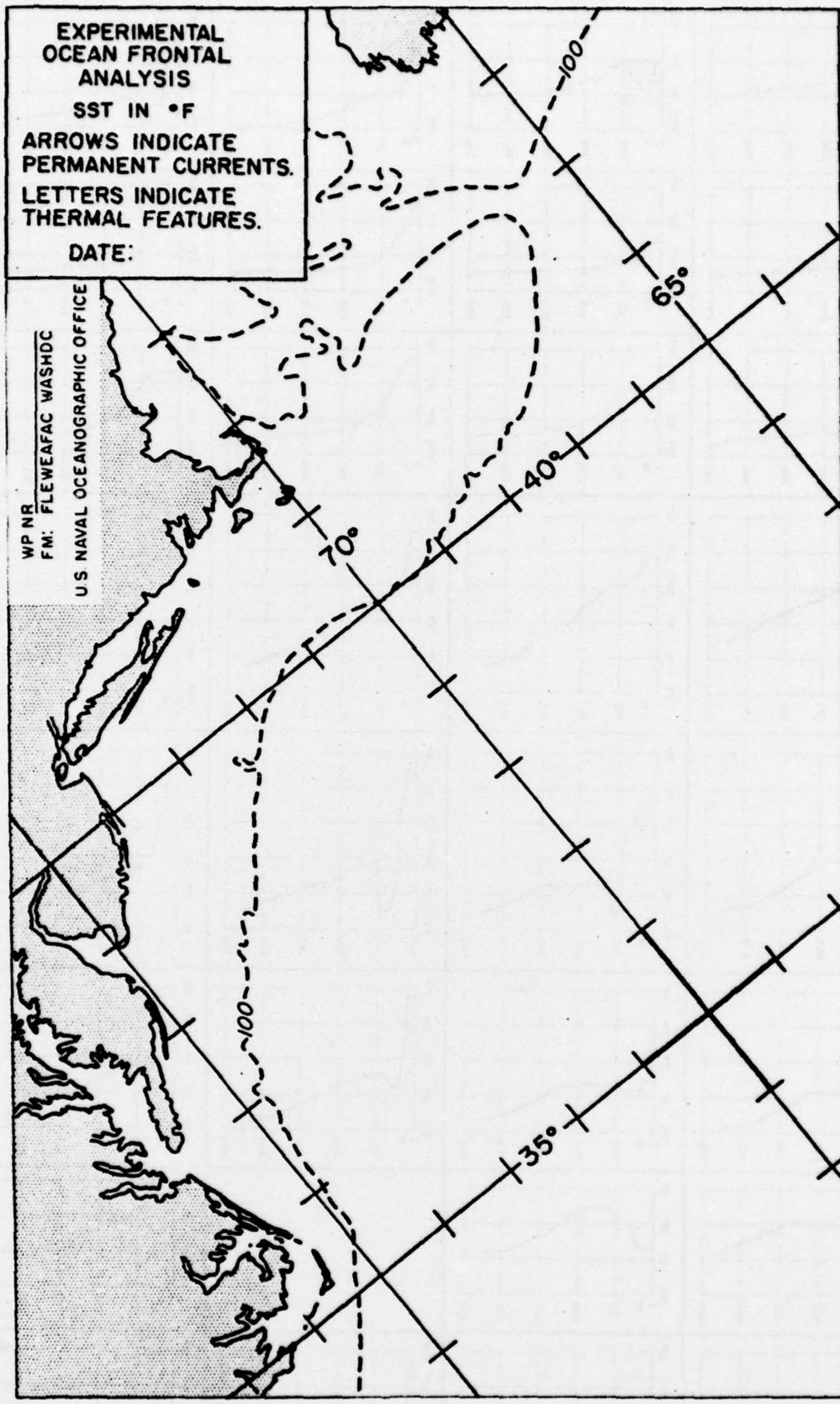

Fig. 1 Base chart, Cape Sable to Cape Hatteras.

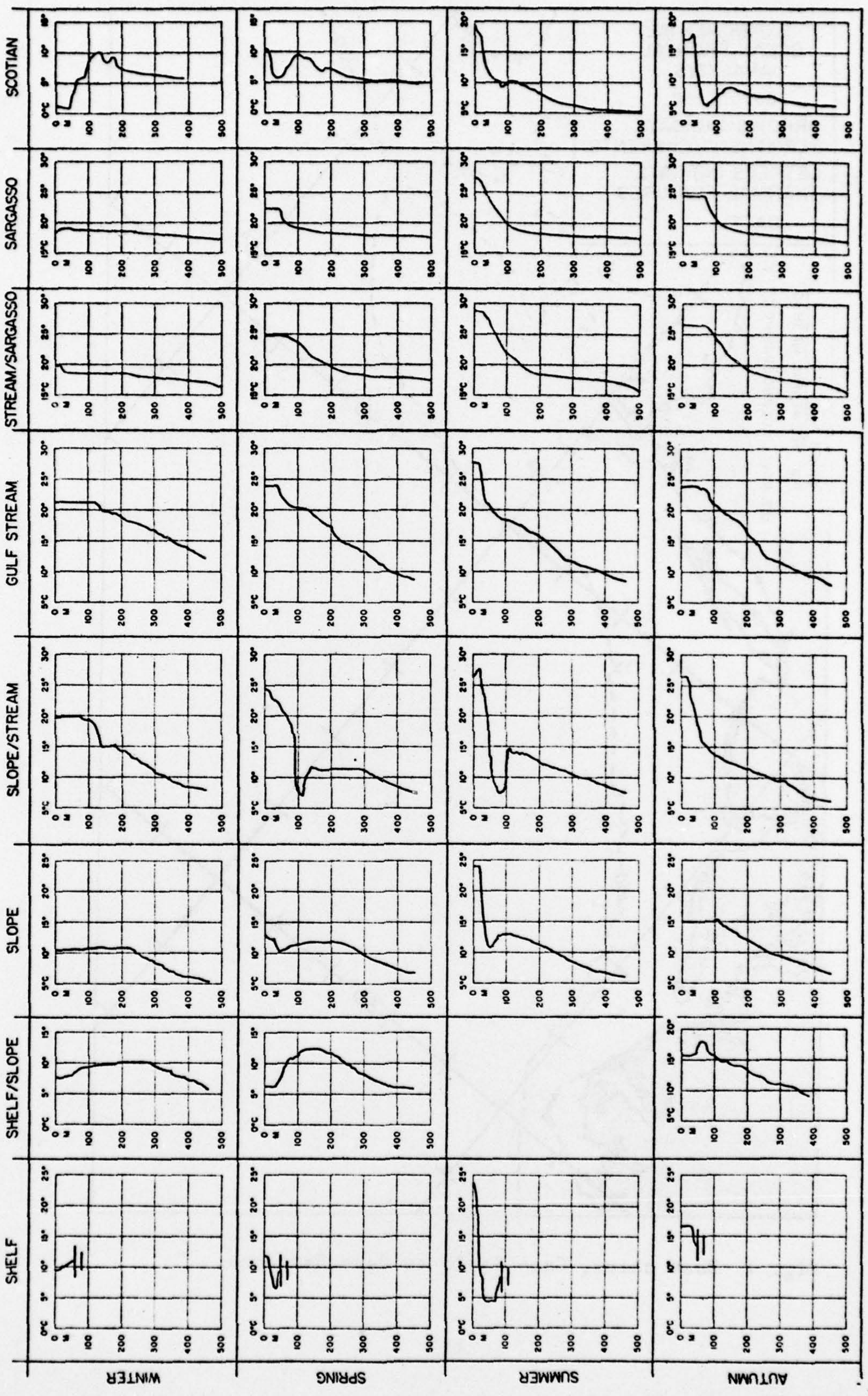

Fig. 2 Typical bathythermograms, Western North Atlantic Ocean

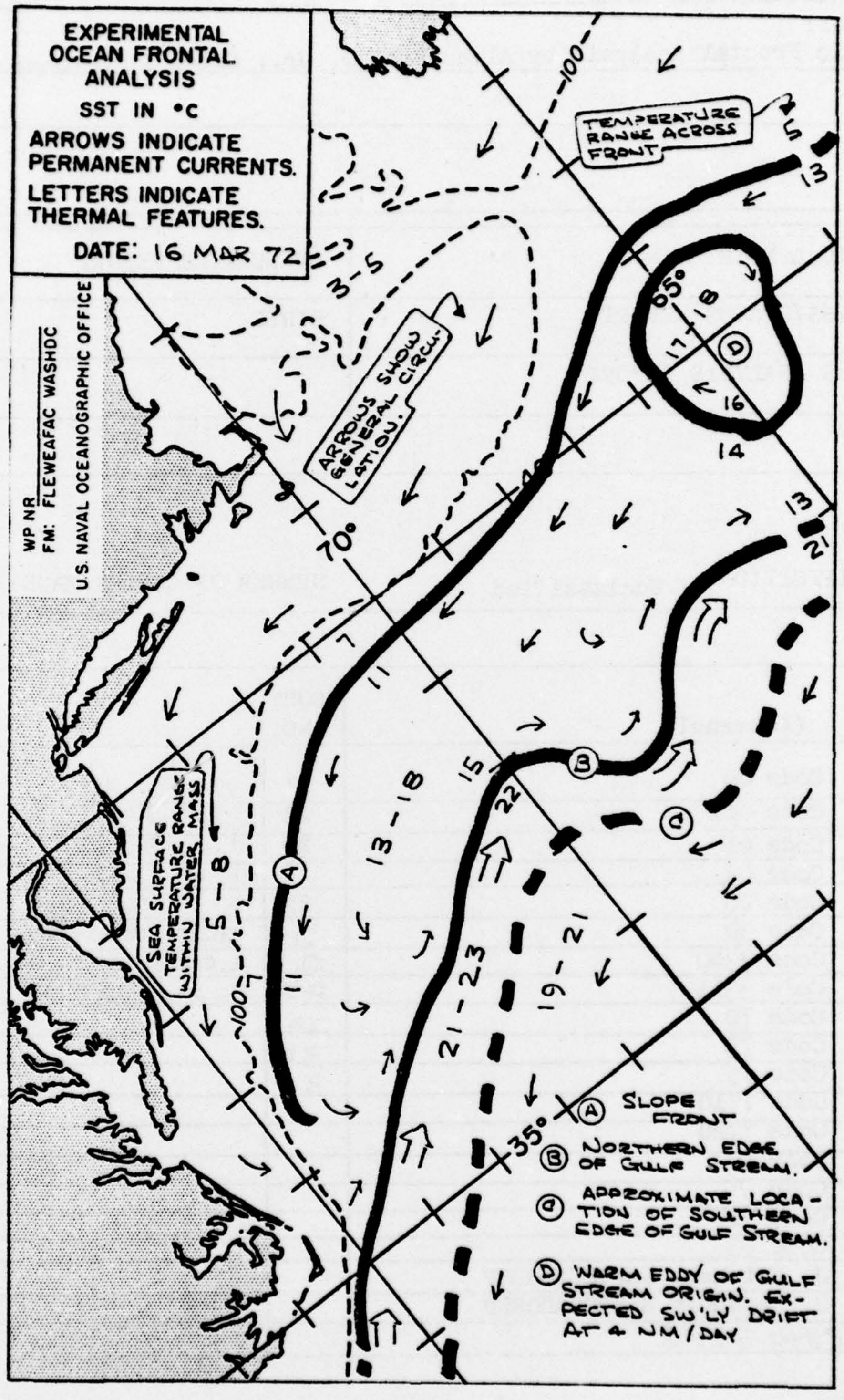

Fig. 3 Oceanic frontal analysis, 16 March 1972

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